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14. ABSTRACT

There are two principal technologies for these large-scale combinatorial optimization problems: 1) exact algorithms and 2) metaheuristic algorithms. This project will integrate concepts from these two technologies to develop generic optimization frameworks to find provably good solutions to large-scale discrete optimization problems often encountered in many real applications. The way that these two sets of methods will be used, and in particular the way in which they will be used together so that each complements the strengths of the other, will be novel and pioneering. In particular, this project will begin by exploring and capitalizing on the links between mixed integer programming decomposition approaches, such as Dantzig Wolfe decomposition and Lagrangian relaxation, and metaheuristics such as the Nested Partitions framework. While the relationship between these seemingly disparate approaches has not been exploited before, there is already evidence to suggest that capitalizing on this relationship to integrate these methods could yield solution frameworks that are more powerful than using either approach on its own.

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Hybrid Nested Partitions and Math Programming Framework for Large-scale Combinatorial Optimization

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1. Summary

Large-scale combinatorial optimization problems are difficult to solve. There are two principal technologies for these problems: 1) exact algorithms (such as linear programming based branch-and-bound and branch-and-cut) that are guaranteed to find optimal solutions within an acceptable amount of computation time, and 2) metaheuristic algorithms such as genetic algorithms, tabu search, and the Nested Partitions (NP) method that aim to quickly find good, but not necessarily optimal, solutions. The relationship between these seemingly disparate approaches has seldom been exploited. In this report, we present our research results on the development of hybrid Nested Partitions and Math Programming framework. Computational results suggest that capitalizing on this relationship to integrate these methods could yield solution frameworks that are more powerful than using either approach on its own.

2. Objectives

The objective of this proposal is to:

- Contribute to the state-of-the-art optimization theory and technologies
- bring innovative perspectives and insights from two separate optimization technologies--exact method and meta-heuristics– to develop generic optimization frameworks to find provably good solutions to large-scale discrete optimization problems often encountered in many real applications
- investigate hybrid approaches that combine Nested Partitions method with math programming techniques for obtaining strong lower bounds
- Investigate new effective decomposition techniques for obtain exact solutions

3. Status of Effort:

In the third year, we investigated hybrid NP-MP approaches for obtaining effective upper bounds. This includes LP-based sampling and other problem depend sampling approaches. In particular, we have developed theoretical results and techniques that can quantify the upper bounds through the proposed hybrid approaches. We also develop effective lower bound for solving difficult scheduling problems. Our research results are summarized in the next section.

4. Accomplishments/New Findings:

Our research results can be summarized in the following publications:

1. Chen, Weiwei, L. Pi, and L Shi, "An Enhanced Nested Partitions Algorithm Using Solution Value Prediction", (in press) *IEEE Trans. on Automation Science and Engineering.*
2. Neil Duffie and L. Shi, "Dynamics of WIP Regulation in Large Production Networks of Autonomous Work Systems," *IEEE Trans. on Automation Science and Engineering,* Vol. 7, pp. 665-670, 2010.
3. Hao H. Zhang, Leyuan Shi, Robert R. Meyer, and Warrant D'Souza , "A two-stage MC Block-Gauss-Seidel approach to IMRT dose optimization", *Physics in Medicine & Biology,* Vol. 55, pp. 883-892, 2010.
4. Wu, T., Shi, L., and Duffie, N., "A New Solution Approach for the Capacitated Multi-level Lot Sizing Problem with Set-up Times" (in press) *IEEE Trans. on Automation Science and Engineering.* Vol. 7, pp. 500-511, 2010.
5. Zhang, CR., Zhang, ZH, L Shi, Armstrong, A., and Zheng, Li, "The Allocation of Berths and Quay Cranes by Using a Sub-gradient Optimization Technique", *Computers and Industrial Engineering,* Vol. 58, pp. 40-50, 2010.
6. Zhang, C., L. Chen, & L. Shi, "A Note on Loading Sequence Optimization of Yard Cranes", *European Journal of Operational Research,* Vol. 205, pp. 483-485, 2010.
7. Hao H. Zhang, Leyuan Shi, Robert R. Meyer, and Warrant D'Souza , "Minimum knowledge base for predicting organ-at-risk dose-volume levels and plan-related complications in IMRT planning," *Physics in Medicine and Biology,* Vol. 55, pp. 1935-1947, 2010.
8. Hao H. Zhang, Leyuan Shi, Robert R. Meyer, and Warrant D'Souza , "Solving Beam Angle Selection and Dose Optimization Simultaneously via High-Throughput Computing ," *INFROMS Journal on Computing,* Vol. 21(3), pp. 427-444, 2009.
9. Hao H. Zhang, Leyuan Shi, Robert R. Meyer, and Warrant D'Souza , "Modeling Plan-Related Clinical Complications using Machine Learning Tools in a Multi-Plan IMRT Framework", (in press) *International Journal of Radiation Oncology*. Vol. 74, 1617-1626, 2009.
10. Yau, Hoksung and Leyuan Shi, "Nested Partitions for the Large-scale Extended Job-shop Scheduling Problem " *Annual of Operations Research.* Vol. 168, (1), 23-39, 2009.
11. Duffie, N.A. and Shi, L.; "Maintaining Constant WIP-Regulation Dynamics in Production Networks with Autonomous Work Systems," *Annals of CIRP*. Vol. 58 (1), 399-402, 2009.

5. Personnel Supported:

Dr. Leyuan Shi, Principal Investigator
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Liang Pi, Graduate student (Ph.D Graduated in May 2009)
Tao Wu, Graduate student (Ph.D. Graduated in September 2010)

6. **New discoveries, inventions, or patent disclosures. (If none, report None.)**

Patent approved on Automated Radiation Treatment Planning, August 2010